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An IoT-enabled Advisory System for Precision Tillage using Machine Learning-based Draft Prediction

ABSTRACT

Tractors are a crucial power source for agricultural operations. Improper tractor-implement matching and uniform field treatment approaches pose challenges to tillage operations using tractors. These practices lead to inefficient input energy utilization and potential soil degradation. Furthermore, existing draft prediction models also lack accuracy in specific operational contexts, hindering the optimization of tillage processes. To address these limitations, this study proposes an innovative precision tillage advisory system that integrates Internet of Things (IoT) technology with advanced machine learning techniques. This study aimed to develop an IoT-enabled advisory system for precision tillage through machine learning-based draft prediction. The research objectives included designing a constant-rate IoT-enabled cone penetrometer, developing an instrumentation system for real-time tractor-implement performance monitoring, creating machine learning models for draft prediction, and implementing a smartphone-based advisory system for precision tillage operations. An IoT-enabled cone penetrometer was designed and developed, demonstrating better accuracy over conventional hand-pushed penetrometers. An IoT-based Tractor-Implement Performance Monitoring System (ITPMS) was created to capture real-time data on key parameters such as forward speed, draft force, GPS location, and tillage depth.

Various machine learning models for draft prediction were developed and evaluated, with the Gradient Boosting Regression (GBR) model achieving R^2 scores of 0.983 and 0.905, outperforming the ASABE standard model with R^2 values of 0.624 and 0.661 for mouldboard and disc ploughs, respectively. A smartphone application, SmartTrac©, was developed to integrate cone penetrometer monitoring, tractor-implement monitoring, ML-based draft prediction, and advisory services. The application provides features such as soil compaction mapping, draft force visualization, tractor-implement matching, and site-specific tillage recommendations.

Results indicated that the constant-rate penetrometer significantly improved measurement consistency compared to the hand-pushed penetrometer. The ITPMS successfully captured real-time performance data with acceptable variability. When compared to the ASABE model, machine learning models, especially GBR, were better at predicting the draft. For the mouldboard plough, MAPE dropped from 23.94% to 4.48%, and for the disc plough, it dropped from 46.32% to 10.96%. This research contributes to the advancement of precision agriculture by integrating IoT technology, machine learning, and smartphone applications to transform conventional tillage practices into dynamically adaptable precision operations. The developed system offers the potential for improved operational efficiency, reduced fuel consumption, and enhanced tillage operation in agricultural practices.

Key words: Precision tillage, Draft prediction, Machine learning, Internet of things, Smartphone application, Tillage advisory system